Strategy Paper on Future Direction of Monitoring for Dry Deposition of EANET

(2011-2015)

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I. Introduction

The Task Force on Dry Deposition Monitoring for the Acid Deposition Monitoring Network in East Asia (EANET) was first established in 1998 by the Interim Scientific Advisory Group (ISAG) of EANET to carry out the following functions:

i) To prepare a draft QA/QC program for the first priority chemicals and particles during the preparatory phase, for consideration and adoption by ISAG, and
ii) To develop a strategy paper for future direction of dry deposition monitoring of EANET, for consideration of ISAG.

The Task Force subsequently produced 2 important documents:

- *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET*, endorsed by ISAG in September 1999
- *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET (Second Edition)* endorsed by the Scientific Advisory Committee (SAC) of EANET in September 2005

The *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET (Second Edition)* had highly recommended the following priority chemical species for EANET dry deposition monitoring in view of their serious impacts on the ecosystem and human health:

First priority: SO_2, O_3, NO, NO_2 (urban), HNO_3, HCl, NH_3, Particulate component (SO_4^{2-}, NO_3^-, Cl^-, NH_4^+, Na^+, Mg^{2+}, K^+ and Ca^{2+}), PM_{10}

Second priority: NO_2 (rural and remote), $PM_{2.5}$

On the recommendation of SAC, the Tenth Session of the Intergovernmental Meeting (IG10) held in Chiang Mai, Thailand in November 2008 agreed to change the name of the Task Force to "Task Force on Monitoring for Dry Deposition" and also agreed to the following new terms of reference for the Task Force:

- To further develop and elaborate the strategy for dry deposition evaluation in the region
- To discuss on future direction of dry deposition evaluation and provide guidance on relevant activities based on the strategy
- To develop the Technical Manuals for Air Concentration Monitoring and Dry Deposition Flux Estimation
- [To review substances to be monitored]

The Strategy Paper on Future Direction of Monitoring for Dry Deposition of EANET (2011-2015) (hereafter referred to as the "Strategy") has been developed by the Task Force in 2009-2010 and submitted to the Tenth Session Scientific Advisory Committee (SAC10) held in 2010 for adoption. The Strategy further elaborates on the *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET (Second Edition)* adopted in September 2005 and will serve as a guide for the Task Force and other related groups for planning and implementing future activities for improving the assessment of acid deposition and other priority chemical species of EANET.

In the development of the Strategy, the Task Force was guided by the Strategy on EANET Development (2006-2010) adopted by the Intergovernmental Meeting (IG) in 2006 and other recent developments within EANET. The views of relevant bodies of EANET were also taken into consideration in the development of the objectives for monitoring of dry deposition in EANET. All the activities recommended shall be undertaken within the financial and human resources available and a transparent system of implementation and evaluation involving all the participating countries of EANET is recommended.

II. Current status

Dry deposition is the process by which gases and particles are deposited directly onto the ground by gravitational settling and atmospheric diffusion; thus, it is difficult to quantify the dry deposition amounts because of the dependency of deposition velocity on meteorological conditions, surface conditions, and chemical species. Direct measurement (e.g., Eddy correlation method) to determine the dry deposition amounts requires costly equipment and, thus, is hard to conduct at many sampling sites simultaneously. On the other hand, a number of preceding studies demonstrated that it is feasible for a routine monitoring activity to estimate the dry deposition amounts by coupling air concentration data with estimated deposition velocity by meteorological measurements. This inferential method is adopted in air pollution monitoring networks, such as the Clean Air Status and Trends Network (CASTNET) in the U.S.A. In CASTNET, the dry deposition amount is estimated by routine atmospheric and meteorological monitoring data (MACTEC, 2008).

The regular phase of EANET activity has been operated since 2001, and wet and dry deposition and ecological impact monitoring activities have been conducted in East Asian region. Regarding dry deposition monitoring, the atmospheric composition has

been measured with a filter-pack and/or an automatic monitor at 42 sites in 10 EANET participating countries as of 2008. However, a methodology to estimate the dry deposition amounts has not been established, and, thus, it is necessary to establish such a methodology and calculate the dry deposition amounts in East Asian region in order to evaluate environmental impacts of total atmospheric deposition. Some field investigations were conducted to verify the inferential method with direct measurements in Japan and Thailand (Takahashi et al., 2002, Matsuda et al., 2005, Matsuda et al., 2006). According to these studies, Matsuda (2007) recently ameliorated his originally developed inferential method to be applied in Japan. Based on these researches on dry deposition, the Expert Group of Dry Deposition Flux Estimation has worked on preparing the Technical Manual on Dry Deposition Flux Estimation to be adopted in SAC 10. After endorsement of the Technical Manual, the NC will start to calculate dry deposition fluxes of all the measurement species at all available monitoring sites because this the first attempt for dry deposition flux estimation. Selection of suitable species and monitoring sites will be considered as the next step.

In addition to dry deposition flux estimation, atmospheric composition data in EANET sites have been used for assessment of regional air quality, trend analysis of atmospheric composition, validation of atmospheric models (An et al., 2002, An et al., 2003, Carmichael et al., 2008, Lin et al., 2008). In future, the utility of EANET data is expected to grow further. Therefore, enhancement of dry deposition monitoring such as sustaining of quality assurance/quality control (QA/QC) of air concentration monitoring, expansion of monitoring items and monitoring sites, and high time frequency of monitoring data are important for satisfying the worldwide demand.

III. Objectives

The *Strategy Paper for Future Direction of Dry Deposition Monitoring of EANET (Second Edition)* recommended a step-wise approach for dry deposition monitoring involving:

Step 1: Implementation of air concentration monitoring for priority chemical species
Step 2: Intensive research on methodology for dry deposition monitoring
- Setting up of special sites, where more direct measurements of dry deposition are initiated
- Selection of schemes for calculating deposition resistances

- Study on the methods for direct flux measurement
- Study on schemes for inferring V_d to resistances R_a, R_b and R_c

Step 3: Selection of specific monitoring sites suitable for dry deposition computation among the air concentration monitoring sites

The step 1 has been conducted in most of EANET participating countries, and the step 2 has been carried out for the last few years. The step 3 will be considered by the compiled results of the estimated dry deposition flux during the next several years.

Considering the current status of monitoring for dry deposition in EANET, the establishment of dry deposition flux estimation and the development of air concentration monitoring at EANET monitoring sites are most important issues in the upcoming years. Consequently, the following future objectives should be achieved during the next medium term of EANET activity (2011-2015).

i) To establish common guidelines of monitoring of air concentration and dry deposition in EANET by means of preparing technical documents and manuals
ii) To provide elaborated air pollutant concentration and dry deposition flux data for the assessment of the adverse effects on soil, inland aquatic systems, vegetation, and human health
iii) To provide spatially distributed atmospheric composition data for validation of atmospheric numerical models and use for assessment of regional air pollution

IV Activities to be implemented to achieve the objectives

The Network Center (NC) for EANET has carried out numerous activities to encourage and assist participating countries to conduct air concentration monitoring of all the priority chemical species in all EANET monitoring sites. Moreover, the following items should be conducted during the next medium term (2011-2015) in order to achieve the above mentioned future objectives.

i) Review on the priority of chemical species to be monitored in EANET

As the first trial of dry deposition flux estimation in East Asian region, dry deposition fluxes of all the measurement species will be calculated at all available monitoring sites. Based on the accumulated data, the applicability of dry deposition flux estimation in East Asia region should be evaluated, and then the suitable and

important chemical species for dry deposition flux estimation should be identified. Moreover, important species for assessment of regional air quality should be also identified.

In the near future, it may be necessary to review the priority chemical species for wet and dry deposition monitoring in EANET and consider the possibility of increasing the number of mandatory parameters to be analyzed in precipitation samples, and include chemical species other than the currently designated priority chemical species in EANET in order to better assess risk of air pollutants.

ii) Develop a technical manual on air concentration monitoring including calibration of automatic instruments

Currently, no technical manual on air concentration monitoring has been produced by EANET although the NC has produced the Technical Document for Filter Pack Method in East Asia which was adopted by SAC in November 2003. In order to obtain comparable and reliable dataset, the standardization of air concentration monitoring methodology and development of technical manual should be promoted as soon as possible. The standardization should agree with those in other monitoring networks in US and Europe. Current specific monitoring methodologies adopted by participating countries should be taken into consideration for the standardization of air concentration monitoring.

iii) Further develop and elaborate the Technical Manual on Dry Deposition Flux Estimation

The Expert Group on Dry Deposition Flux Estimation was established under the Task Force on Monitoring for Dry Deposition in 2007 to produce the Technical Manual on Dry Deposition Flux Estimation for EANET by the end of 2010. The preparation of this manual is one of the important activities identified in the Strategy on EANET Development (2006-2010). The manual will identify suitable type of sites for conducting direct measurements of dry deposition flux as mentioned in the Steps 2 and Step 3 described above. To implement the Technical Manual, the NC is developing a set of software to be provided to all participating countries to enable them to estimate dry deposition of selected parameters using the inferential method at their national sites.

Because application of the inferential method in East Asian region is underdeveloped, elaboration of the inferential method is indispensable. EANET, through the Task Force on Monitoring for Dry Deposition, is implementing a priority research project to determine the aerosol deposition flux and velocity over the forest canopy in a tropical area. The 2-year research project (2009-2010) is being conducted by a researcher of King Mongkut's University of Technology, Thonburi in a deciduous forest in Ratchaburi province, Thailand in collaboration with the NC. The NC will continue to collaborate with scientists from the participating countries to make direct measurements of dry deposition flux for other chemical species and under various types of environmental conditions to improve the current estimations of deposition velocities. By those basic researches, the parameterization to calculate dry deposition velocity should be updated based on future studies on comparison with direct measurement method at special sites. Especially, the studies on aerosols and nitrogen compounds should be encouraged, because of their large uncertainties.

iv) Revise the QA/QC program for air concentration monitoring

In 2001, the document of QA/QC program for the Air Concentration Monitoring in East Asia was produced by the NC. Also the inter-laboratory comparison project on dry deposition has been implemented since 2005 in order to check analytical validity of filter pack samples. The current QA/QC document mainly focusing on the use of automatic instruments should be expanded to include filter pack and passive sampler. Establishment of calibration system for automatic instruments should be described in the QA/QC program. The NC will revise the QA/QC program for air concentration monitoring in the near future.

v) Enhancement of spatial coverage for dry deposition flux estimation

The present number of monitoring sites for air concentration is inadequate to clarify the state of the atmospheric environment in the vast region of East Asia. Moreover, not all the current air concentration monitoring sites are measuring all the recommended priority chemical species for EANET.

The participating countries should therefore make more effort to establish additional monitoring sites, particularly in the data-sparse areas, taking into consideration geographic, climate and ecological conditions. The atmospheric environment in urban sites and the other sites especially exposed to transboundary air pollution, dust storms

and active volcanoes, places with sensitive ecosystems, and national heritage sites may need closer monitoring.

In order to enhance the spatial coverage, the NC will continue to promote continuous measurements of air concentrations by participating countries using automatic real-time monitoring instruments as well as lower cost methodologies such as filter packs, denuders or passive samplers, whichever is most suited to the needs of the country and circumstances at the site. It should be emphasized that the instruments should be regularly calibrated to minimize error and maintain integrity of the measurements.

vi) Promotion of an ozone monitoring network and review of its current status in East Asia

The measurement of surface ozone has been recommended as a first priority activity for EANET. However, there are limited number of EANET sites which are measuring ozone, with some countries using automatic analyzers and some using passive samplers. Moreover, the sampling period varies in some countries. Recent satellite imageries indicate that ozone is a growing problem in East Asia. The non-uniformity of the measurements has made it difficult for EANET to analyze the severity and extent of the ozone problem.

It has been suggested that high concentrations of ozone may be harmful to the growth of trees and crops and specific visible injuries of plant leaves caused by ozone have been identified as indicators for observation of direct effects of this pollutant on plants. The NC produced a brochure “Tropospheric Ozone: A Growing Threat” in 2006. High concentrations of ozone have been reported in some participating countries of EANET. Therefore, the accumulation of ozone date in forest areas should also be considered for future assessment of ozone impacts.

Further efforts should be made to promote an ozone monitoring network. This may be achieved by securing the necessary financial resources to purchase and install at least one set of automatic monitoring instruments in each country and a traveling standard for regular calibration of the network instruments, traceable to the NIST (National Institute of Standards and Technology, U.S.A.) Standard Reference Photometer (SRP). Additional monitoring of ozone may be carried out in the countries using passive samplers, particularly in rural and forest sites to supplement the network.

vii) Promotion of a PM_{10}/$PM_{2.5}$ monitoring network and review of their current status in East Asia

Although PM_{10} and $PM_{2.5}$ has also been designated as the priority chemical species for EANET dry deposition monitoring, only several counties are implementing monitoring by automatic analyzers. Since concentrations of secondary aerosol precursors such as, SO_2, NOx and VOC are recently increasing in major cities of Asian region, the future trends of PM mass concentrations must be monitored at many sites.

Particles less than 10 micrometers in diameter cause serious problems, because they can generally pass through the throat and nose and enter the lungs, and some may even get into the bloodstream. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. Furthermore, fine particles may affect climate change in two ways: direct radiative forcing such as scattering of solar radiation and the absorption/emission of terrestrial radiation and indirect radiative forcing such as effects of aerosols on cloud properties. Recently finer particle matter such as $PM_{2.5}$ has been attracting a lot of attention because of its more adverse health effects.

Besides as an ozone monitoring network, a PM_{10}/$PM_{2.5}$ monitoring network should be promoted in East Asia. This activity may include acquiring financial support to purchase and install at least one set of automatic monitoring instruments for PM_{10} (first priority) and $PM_{2.5}$ (second priority) in each country.

Since the importance of the adverse effects of PM has not been sufficiently recognized in EANET participating countries in comparison with acidic substances, it is necessary to provide information of potential risk of PM. The NC will continue to review the effects PM in order to make clear the impacts of PM as well as ozone.

viii) Develop the database for surface resistances of tropical and boreal regions

The Technical Manual on Dry Deposition Flux Estimation defines 15 land use and 5 seasonal categories in order to identify surface resistance parameters such as the Roughness length "z_0"(m) and characteristic radius of plants "A" (mm). The adopted category was referred from Brook et al. (1999), which was originally reported in Wesely (1989) and generally applied for mid latitude region. In order to apply surface resistance in the whole EANET region, survey of surface resistance applied in tropical and boreal region is necessary. The NC will develop surface the database for surface

resistances of tropical and boreal regions by means of reviewing existing researches and with aid of the members of the Expert Group on Dry Deposition Flux Estimation.

V. Capacity building of dry deposition monitoring activities

The NC will continue to support participating countries to build capacity in dry deposition monitoring activities. For example, the NC will make an effort to hold individual training courses/workshops/seminars for responsible persons of dry deposition monitoring. The NC should also make full use of training courses organized by international cooperation organization such as Japan International Cooperation Agency (JICA). This capacity building will be carried out with the cooperation of the members of the Expert Group on Dry Deposition Flux Estimation and the Expert Group on Preparation of the Technical Manual for Air Concentration Monitoring.

Compared to wet deposition monitoring, contact information on experts of air concentration monitoring and dry deposition study is not easily available in East Asia. The NC will compile a list of national experts on atmospheric environment especially in the fields of air quality and dry deposition in East Asia in order to keep them informed on recent developments in dry deposition monitoring and related research activities in EANET participating countries.

VI. Collaboration with relevant networks/organizations

Collaboration with other networks and organizations is essential to address regional and global air pollution issues and also to ensure the sustainability and future growth of EANET. Till now, EANET has continued to build and strengthen links with some international/domestic programmes and initiatives such as the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe (EMEP) under the Convention on Long-Range Transboundary Air Pollution (CLRTAP) and the World Meteorological Organization (WMO), Clean Air Status and Trends Network (CASTNET). The collaborative works implemented by the NC covers:

- Joint research studies on air concentration monitoring and dry deposition flux estimation in the EANET region involving researchers from NC, participating countries and interested external scientists.
- Participating in activities organized by other international/regional initiatives.
- Coordinating investigations on global or inter-regional transport of air pollutant which threaten human health and ecosystems.
- Learning the good practices for addressing regional and transboundary air pollution problems, including application of modeling and emission inventories, evaluation of long-term effects, control and mitigation measures, etc.

EANET should continue to seek opportunities to inform and update the international and regional scientific programs and potential funding agencies on EANET activities, highlighting the significance and achievements since the start of its regular activities, and the need to continue efforts to promote a comprehensive approach to relevant environmental problems. Future collaboration should focus on the following:

i) Seeking the ways to strengthen the existing cooperation with EMEP, WMO, Regional Forum on Environment and Health developed jointly by WHO and UNEP.
ii) Building partnerships and linkages with other programs in the region such as Deposition of Biogeochemically Important Trace Species of the International Geosphere-Biosphere Programme (IGBP-DEBITS), Malé Declaration in South Asia and ASEAN Haze Agreement.

VII. Roadmap and milestones

The time schedules of respective activities corresponding to the items described in the Chapter IV are shown below. Also these time schedules are summarized in the Appendix 1.

i) Develop a technical manual on air concentration monitoring including calibration of automatic instruments

The Task Force on Monitoring for Dry Deposition will establish an Expert Group on Preparation of the Technical Manual for Air Concentration Monitoring composed of relevant experts in this field. The Expert Group will consider current country specific monitoring methodologies of air concentration monitoring and necessary calibration

procedures for the automatic monitors and prepare a Technical Manual for Air Concentration Monitoring for EANET. The Technical Manual will be adopted at SAC 13 in 2013.

ii) Review on the priority of chemical species to be monitored in EANET

Based on the compiled atmospheric composition and dry deposition flux data, the Task Force on Monitoring for Dry Deposition may review the list of priority chemical species for dry deposition monitoring in EANET and recommend modifications, if any, in 2014 – 2015. The outcomes of the review will be reflected in the contents of the next version of the *Technical Manual on Dry Deposition Flux Estimation* and the *Technical Manual for Air Concentration Monitoring*.

iii) Further develop and elaborate the Technical Manual on Dry Deposition Flux Estimation

The Expert Group on Dry Deposition Flux Estimation established in 2008 is in the process of preparing a Technical Manual on Dry Deposition Flux Estimation. The Technical Manual will be finalized and submitted to SAC 10 in 2010 for adoption. The parameterization of dry deposition velocity will be reviewed by the Task Force on Monitoring for Dry Deposition with help of appropriate experts in 2011, 2013 and 2015.

iv) Revise the QA/QC program for air concentration monitoring

The NC is in the process of developing a combined QA/QC program for EANET monitoring. On completion of the Technical Manual for Air Concentration Monitoring by the Expert Group on Preparation of the Technical Manual for Air Concentration Monitoring, the NC will revise and update the QA/QC program to include air concentration monitoring. The revision of the QA/QC program will be carried out in 2012 – 2013.

v) Enhancement of spatial coverage for dry deposition flux estimation

The NC in cooperation with participating countries will continue to make effort to expand the network of air concentration monitoring sites and encourage the monitoring of all priority chemical species in 2011 – 2015.

vi) Promotion of an ozone monitoring network and review of its current status in East Asia

To strengthen the existing network, the NC will encourage participating countries to establish more surface ozone monitoring sites using national resources in 2011 – 2015. The NC will also try to provide and install an ozone monitor in developing countries which do not have sufficient resources to acquire an ozone monitor. Each ozone monitor in EANET shall be calibrated using an ozone calibrator traceable to the NIST SRP at least once every two years. Within the next two years, the NC will acquire an ozone secondary standard calibrator, to be available to participating countries upon the request.

vii) Promotion of a PM_{10}/$PM_{2.5}$ monitoring network and review of their current status in East Asia

The NC will also encourage participating countries to establish more PM mass concentration monitoring sites using national resources in 2011 – 2015. The NC will also try to provide and install a PM monitor in developing countries which do not have sufficient resources to acquire a PM monitor.

viii) Develop the database for surface resistances of tropical and boreal regions

The NC will review of existing researches of estimating dry deposition velocity in tropical and boreal regions in 2011 – 2015. Furthermore, in collaboration with the members of the Expert Group on Dry Deposition Flux Estimation, the NC will summarize the outcomes of dry deposition study in tropical region such as Thailand and boreal region such as northern Japan.

Appendix 1

Time schedule of implementation of activity

Activity	2011	2012	2013	2014	2015
Develop a technical manual on air concentration monitoring including calibration of automatic instruments	X	X	X		
Review on the priority of chemical species to be monitored in EANET				X	X
Further develop and elaborate the Technical Manual on Dry Deposition Flux Estimation	X		X		X
Revise the QA/QC program for air concentration monitoring		X	X		
Enhancement of spatial coverage for dry deposition flux estimation	X	X	X	X	X
Promotion of an ozone monitoring network and review of its current status in East Asia	X	X	X	X	X
Promotion of a PM_{10}/$PM_{2.5}$ monitoring network and review of their current status in East Asia	X	X	X	X	X
Develop the database for surface resistances of tropical and boreal regions	X	X	X	X	X

Appendix 2

Members of the Task Force on Monitoring for Dry Deposition
(As of May, 2010)

1.	Prof. Cho Seog-Yeon (Chair)	Inha University, Republic of Korea
2.	Mr. Chhek Roth / Mr. Kong Savuth	Ministry of Environment, Cambodia
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5.	Prof. Shiro Hatakeyama	Tokyo University of Agriculture and Technology, Japan
6.	Ms. Setouvanh Phanthavongsa	Water Resources and Environment Research Institute, Lao PDR
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9.	Ms. Htwe Htwe Win	Department of Metrology and Hydrology (DMH), Myanmar
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11.	Dr. Chang Lim-Seok	National Institute of Environmental Research (NIER), Republic of Korea
12.	Dr. Tamara V. Khodzher	Limnological Institute of the Siberian Branch of the Russian Academy of Sciences (RAS/SB), Russia
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